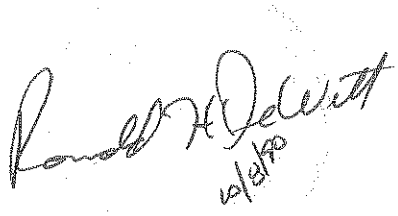
October 8, 1990
REPORT

RESULTS OF PUMPING TEST
TUCSON WATER WELL (D-16-10)8BDD[AF-64]
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA



Prepared For

TUCSON WATER

by

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in association with

CH2M HILL

and

Dr. L. G. Wilson

October 8, 1990
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SUMMARY AND CONCLUSIONS

Results of pumping test operations at the Brawley Wash pilot surface recharge site are summarized as follows:

1. A constant-yield pumping test was conducted at the Brawley Wash pilot surface recharge site during the period February 8 through 28, 1990. Measurements of pumping rate, and of water level drawdown in pumped well (D-16-10)8bdd[AF-64] and in monitor wells (D-16-10)8bdb1[WR-157A], (D-16-10)8bcd[WR-158A], (D-16-10)8bdb2[WR-159A], and (D-16-10)8bca1[WR-160A] were analyzed to estimate transmissivity and storage coefficient of the aquifer at the Brawley Wash site.

2. Pre-pumping water level was 154 feet below land surface at pumped well AF-64. Average pumping rate during the 20-day pumping period was about 620 gallons per minute (gpm). Maximum drawdown in pumped well AF-64 occurred near the end of the 20-day period and was 32 feet. Specific capacity of well AF-64 at the end of the 20-day period was 19 gallons per minute per foot of drawdown.

3. Pre-pumping water levels at the four monitor wells ranged from 150 to 152 feet below land surface. Maximum drawdown of water

levels in the monitor wells occurred near the end of the 20-day pumping period and was 0.5 foot at monitor wells WR-158A and WR-160A, and 0.9 foot at monitor wells WR-157A and WR-159A.

4. Based on analysis of water level drawdown data, transmissivity for the aquifer at the Brawley Wash site is judged to be about 80,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient (gpd/ft). Storage coefficient is approximately 0.20 (dimensionless; ratio of volume of water released per unit surface area per unit decline in head). Average hydraulic conductivity for the saturated strata penetrated by pumped well AF-64 was computed to be 320 gallons per day per square foot of aquifer at 1:1 hydraulic gradient.

5. The duration of pilot surface recharge operations at the Brawley Wash site is planned to be six months or longer from February 12, 1990. Magnitude of projected water level drawdown due to pumping at well AF-64 should be considered for analysis of water level rise during pilot surface recharge operations. Based on transmissivity of 80,000 gpd/ft, storage coefficient of 0.20, and continuous pumping rate of 620 gpm, projected water level drawdown after six months of pumping would range from 1.6 feet at monitor well WR-158A to 2.6 feet at monitor well WR-159A.

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REPORT

RESULTS OF PUMPING TEST TUCSON WATER WELL (D-16-10)8bdd[AF-64] BRAWLEY WASH PILOT SURFACE RECHARGE SITE PIMA COUNTY, ARIZONA

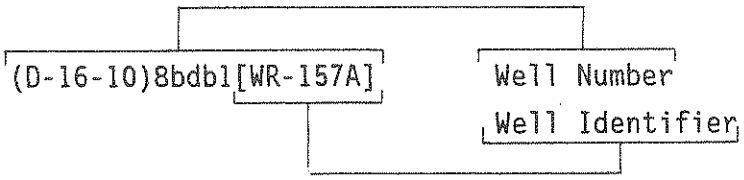
INTRODUCTION

This report gives results of a 20-day pumping test at Tucson Water well (D-16-10)8bdd[AF-64] at the Brawley Wash pilot surface recharge site. Location of the pilot recharge site is shown on Figure 1. Well AF-64 is the source of water for pilot surface recharge tests at the site. Pumping at well AF-64 started on February 8, 1990; pilot recharge testing started on February 12, 1990, and is planned to continue for a period of six months or longer. This report gives results for the initial 20-day pumping period from February 8 through 28, 1990. Data obtained during this period were analyzed to:

1. Estimate transmissivity and storage coefficient for the aquifer at the site.

2. Project the magnitude of water level drawdown which would result from continued pumping for pilot surface recharge tests.

Water level measurements were made in the pumped well and in four monitor wells during the 20-day pumping period. Well numbers and identifiers for the four monitor wells are as follows:



(D-16-10)8bcd[WR-158A]
(D-16-10)8bdb2[WR-159A]
(D-16-10)8bca1[WR-160A]

Nine vadose zone piezometers at the Brawley Wash site are being used to monitor occurrence of perched groundwater during pilot surface recharge operations. Drilling and construction of the four monitor wells and nine piezometers were described in a previous report: "RESULTS OF HYDROGEOLOGIC INVESTIGATIONS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE" (Montgomery & Associates, 1990). Locations for wells and piezometers at the Brawley Wash test site are shown on **Figure 2**.

Records for pumped well AF-64 indicate that the well was drilled in May 1952 to a depth of 232 feet, and was cased with 16-inch diameter steel casing to 228 feet below land surface. Perforated interval for the 16-inch casing is reported to be from 163 to 220 feet. The well was deepened to 555 feet and 181 feet of 10-inch diameter casing was installed. The date of the deepening and the depth and perforated interval of the 10-inch casing are not known (oral communication, Gerald J. Huerstel, Hydrologist, Tucson Water, May 1989). Well construction data indicate that the total length of casing installed is 409 feet. Because the 10-inch and 16-inch casing may overlap, cased depth of well AF-64 is believed to be about 400 feet. The well is believed to fully penetrate the upper Tinaja beds and to partially penetrate the lower Tinaja beds.

PREVIOUS PUMPING TESTS

Well AF-64

A 24-hour constant-yield pumping test was conducted at well AF-64 by Tucson Water on November 25, 1986. Pre-pumping water level was 160 feet below land surface. Average pumping rate for the period ending 235 minutes after pumping started was 890 gallons per minute (gpm). Average pumping rate from 235 minutes until 1,445 minutes, when pumping stopped, was 870 gpm. Specific capacity was 11 gallons per minute per foot of drawdown (gpm/ft) at the end of the 24-hour pumping period. Specific capacity of a well is computed by dividing the pumping rate by drawdown at that rate.

Measurements of depth to water level during the pumping period were graphed by Tucson Water as depth to water versus logarithm of time after pumping started. Analysis of the trend of drawdown data for the period from about 235 to 1,440 minutes after pumping started indicated transmissivity of 85,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient (gpd/ft).

Measurements of depth to water level during the recovery period were graphed by Tucson Water as depth to water versus logarithm of time after pumping stopped. Analysis of the trend of recovery data for the period from about 30 to 220 minutes after pumping stopped indicated transmissivity of 290,000 gpd/ft. Analysis of the trend of recovery data for the period from about 250 to 720 minutes after pumping stopped indicated transmissivity of 440,000 gpd/ft.

Recovery data from the 1986 test were graphed by Montgomery & Associates as residual drawdown versus the ratio t/t′, where "t" is time after pumping started and "t′" is time after pumping stopped. Residual drawdown is the magnitude of drawdown remaining at any time after pumping stopped. Analysis of the trend of residual drawdown data for the period t/t′ from 104 to 3

(from 14 to 720 minutes after pumping stopped) indicates transmissivity of about 280,000 gpd/ft.

Monitor Wells WR-157A through WR-160A

Constant-yield pumping tests of 12-hours duration were conducted for monitor wells WR-157A, WR-158A, WR-159A, and WR-160A during June and July 1989 (Montgomery & Associates, 1990). Perforated intervals and pre-pumping water levels for the monitor well are summarized as follows:

MONITOR WELL	PERFORATED INTERVAL (feet below land surface)	PRE-PUMPING WATER LEVEL (feet below land surface)
WR-157A	130-200	150.04
WR-158A	131-201	151.44
WR-159A	145-200	150.51
WR-160A	146-176	150.50

During the 12-hour tests, average pumping rates ranged from 33 gpm at monitor well WR-157A to 61 gpm at monitor WR-158A. Maximum drawdown during the 12-hour pumping period ranged from 3.66 feet at monitor well WR-158A to 15.41 feet at monitor well WR-159A. Analysis of results of the 12-hour pumping tests indicated that transmissivity for the part of the aquifer penetrated by the monitor wells ranged from about 11,000 to 28,000 gpd/ft. Computed hydraulic conductivity for the part of the aquifer penetrated by the monitor wells ranged from 220 to 1,100 gallons per day per square foot of aquifer at 1:1 hydraulic gradient (gpd/ft^2).

PUMPING TEST PROCEDURES
20-DAY PUMPING TEST

Prior to pumping well AF-64 for pilot surface recharge operations, water levels at wells WR-157A, WR-158A, WR-159A, and WR-160A were monitored for a period of about seven months. Analysis of water level hydrographs for the monitor wells indicates that average rate of groundwater level rise was about 0.003 feet per day for the period from November 1989 until pumping started on February 8, 1990.

Pumping at well AF-64 started at 13:30 on February 8, 1990. During the first four days of pumping, water was discharged into a concrete-lined irrigation canal at well AF-64, conveyed northwest from well AF-64 via the canal, and siphoned from the canal onto retired farmland. Beginning at about 10:30 on February 12, water was conveyed via pipeline to the pilot recharge basins approximately 1,450 feet northwest from the pumped well.

During the 20-day pumping period, measurements of water level were made in well AF-64 and in the monitor wells. Measurements of temperature, specific electrical conductance, and pH of the pumped water were made at well AF-64. Pumping rate was measured using a Data Industrial flow sensor installed in the discharge pipeline at well AF-64 and using two McCrometer flow meters installed in the two water supply pipelines for the pilot recharge test basins and the waste basin. The flow sensor, and gate valve downstream from the flow sensor were used to maintain constant discharge rate.

Average pumping rate for the 20-day pumping period was 620 gpm and was computed based on measurements obtained by CH2M HILL from the McCrometer flow meters. Approximately 18 million gallons of water, or about 55 acre-feet, were pumped during the 20-day period. Of this total, 3.6 million gallons, or 11 acre-feet, were pumped into the irrigation canal during the first four days of pumping, and 14.4 million gallons, or 44 acre-feet, were pumped into the pilot recharge basins. With two exceptions, pumping rate ranged from

about 615 to 635 gpm during the initial 20-day pumping period. During the periods from about 10:30 to 11:10 on February 12 (5,580 to 5,610 minutes after pumping started) and from about 09:20 to 15:40 on February 15 (9,830 to 10,210 minutes after pumping started), average pumping rate was larger than 635 gpm. The larger pumping rates during these periods were caused by opening of valves in the supply pipeline for pilot surface recharge operations.

Water level measurements in the pumped well were obtained with an electric sounder. Water level measurements in the monitor wells were obtained with electric sounders and with GEOKON vibrating wire pressure transducers. Measurements of change in barometric pressure were also obtained using a GEOKON vibrating wire pressure transducer installed at a depth of 20 feet in piezometer WR-160C. Data from the pressure transducers were recorded automatically by a GEOKON Micro-10 datalogger.

ANALYSIS OF PUMPING TEST RESULTS

Measurements of water level made in pumped well AF-64 during the 20-day pumping period were analyzed to determine transmissivity using the modified non-equilibrium equation semi-logarithmic graphical procedure developed by Cooper and Jacob (1946). Jacob (1950) indicated that the Cooper-Jacob method should only be used to analyze drawdown data for which the numerical value of the argument of the well function "u" is less than 0.01. Because of the large distance from the pumped well to the monitor wells, the value of "u" for drawdown data obtained from the monitor wells was substantially larger than 0.01 during the 20-day period, and would be less than 0.01 only after pumping for more than one year. Therefore, water level drawdown data obtained for the monitor wells during the 20-day period were analyzed to estimate transmissivity and storage coefficient using the Theis log-log graphical procedure (Jacob, 1940).

Water levels in the pumped well and the monitor wells responded to the effects of pumping and to the effects of changes in barometric pressure at the site. Figures 3 through 6 are water level hydrographs for monitor wells WR-157A, WR-158A, WR-159A, and WR-160A during the 20-day pumping period. Comparison of changes in barometric pressure with changes in water level drawdown indicate that water levels measured in the monitor wells were influenced by barometric pressure. Water level drawdown in the monitor wells was adjusted for changes in barometric pressure prior to analysis for aquifer parameters.

Figure 7 is a semi-logarithmic drawdown graph for pumped well AF-64 during the 20-day pumping period. Log-log graphs of adjusted drawdown for the monitor wells during the 20-day pumping period are shown on Figures 8 through 11. Transmissivity and storage coefficient computed from analysis of pumping test results are summarized in Table 1.

PUMPED WELL (D-16-10)8bdd[AF-64]

Pumping started at well AF-64 at 13:30 on February 8, 1990. Pre-pumping water level was 154.35 feet below land surface. Water level drawdown at the end of the 20-day pumping period was 32 feet; specific capacity at the end of the pumping period was 19 gpm/ft.

The temperature of the pumped water ranged from about 23 to 26 degrees Celsius (°C) during the 20-day period; average was 24.6°C. Field measurements for specific electrical conductance ranged from 354 to 425 micromhos per centimeter (μmho/cm); average was 381 μmho/cm. Specific electrical conductance is defined as the conductance of a cube of water, one centimeter on a side, at 25°C and has units of μmho/cm. The pH of the pumped water ranged from about 7.5 to 8.3; average was 7.9.

Figure 7 is a semi-logarithmic drawdown graph for pumped well AF-64 during the initial 20-day pumping period. Analysis of the trend of drawdown data for the period from five to 65 minutes after pumping started indicates transmissivity of 58,000 gpd/ft. The trend of data from 180 to 2,150 minutes indicates transmissivity of 78,000 gpd/ft. The trend of data from 5,910 to 15,810 minutes indicates transmissivity of 44,000 gpd/ft (Table 1).

MONITOR WELL (D-16-10)8bdb1[WR-157A]

Figure 8 is a log-log drawdown graph for monitor well WR-157A during the initial 20-day pumping period for pumped well AF-64. Monitor well WR-157A is located 1,160 feet northwest from the pumped well (Figure 2). Analysis of the trend of drawdown data for the period from about 17,000 to 28,800 minutes after pumping started indicates transmissivity of 82,000 gpd/ft and storage coefficient of 0.18 (dimensionless; ratio of volume of water released per unit surface area per unit decline in head) (Table 1).

MONITOR WELL (D-16-10)8bcd[WR-158A]

Figure 9 is a log-log drawdown graph for monitor well WR-158A during the initial 20-day pumping period for pumped well AF-64. Monitor well WR-158A is located 1,980 feet west-northwest from the pumped well (Figure 2). Analysis of the trend of drawdown data for the period from about 17,000 to 28,800 minutes after pumping started indicates transmissivity of 97,000 gpd/ft and storage coefficient of 0.11 (Table 1).

MONITOR WELL (D-16-10)8bdb2[WR-159A]

Figure 10 is a log-log drawdown graph for monitor well WR-159A during the initial 20-day pumping period for pumped well AF-64. Monitor well WR-159A is located 1,070 feet northwest from the pumped well (Figure 2). Analysis of the trend of drawdown data for the period from about 17,000 to 28,800 minutes after pumping started indicates transmissivity of 79,000 gpd/ft and storage coefficient of 0.20 (Table 1).

MONITOR WELL (D-16-10)8bca1[WR-160A]

Figure 11 is a log-log drawdown graph for monitor well WR-160A during the 20-day pumping period for pumped well AF-64. Monitor well WR-160A is located 1,470 feet northwest from the pumped well (Figure 2). Analysis of the trend of drawdown data for the period from about 17,000 to 28,800 minutes after pumping started indicates transmissivity of 78,000 gpd/ft and storage coefficient of 0.22 (Table 1).

SUMMARY

Transmissivity was computed using the Cooper-Jacob semi-logarithmic method for pumped well AF-64, and the Theis log-log graphical method for monitor wells WR-157A, WR-158A, WR-159A, and WR-160A. Correct magnitude of transmissivity computed using drawdown data obtained at pumped well AF-64 is judged to be 78,000 gpd/ft. Transmissivities computed using drawdown data from monitor wells WR-157A, WR-158A, WR-159A, and WR-160A are 82,000, 97,000, 79,000, and 78,000 gpd/ft, respectively. Transmissivity for the aquifer at the Brawley Wash site is judged to be approximately 80,000 gpd/ft.

Storage coefficient computed from drawdown data for the four monitor wells using the Theis log-log graphical method ranges from 0.11 to 0.22. Results indicate that the Tinaja beds aquifer at the Brawley Wash site responded as an unconfined aquifer during the period from about 11 to 20 days after pumping started; magnitude of storage coefficient for the aquifer for this period is judged to be approximately 0.20 (Table 1).

Average horizontal hydraulic conductivity for the aquifer at well AF-64 was computed by dividing transmissivity by pre-pumping saturated interval penetrated by well AF-64. Based on a pre-pumping water level of 154 feet and a total depth of about 400 feet, pre-pumping saturated interval was about 250 feet. Average hydraulic conductivity for the saturated strata penetrated by well AF-64 is about 320 gpd/ft^2.

Average hydraulic conductivities were 220, 320 and 520 gpd/ft^2 for the upper 50 feet of the aquifer, based on results of previous 12-hour pumping tests at monitor wells WR-157A, WR-158A, and WR-159A (Montgomery & Associates, 1990). Average hydraulic conductivity was 1,100 gpd/ft^2 for the upper 25 feet of the aquifer, based on results of the 12-hour pumping test at monitor well WR-160A. Comparison of computed hydraulic conductivity at well AF-64 to computed hydraulic conductivities for the upper 50 feet of the aquifer at monitor wells WR-157A, WR-158A, and WR-159A indicates that computed average hydraulic conductivity for the upper 250 feet of the aquifer

penetrated by well AF-64 is similar to computed average hydraulic conductivity for the upper 50 feet of the aquifer penetrated by the monitor wells.

The duration of pilot surface recharge operations at the Brawley Wash site is planned to be six months or longer. Magnitude of projected water level drawdown due to pumping at well AF-64 should be considered for analysis of water level rise during pilot surface recharge operations. Based on transmissivity of 80,000 gpd/ft, storage coefficient of 0.20, and continuous pumping rate of 620 gpm, projected water level drawdown after six months of pumping would range from 1.6 feet at monitor well WR-158A to 2.6 feet at monitor well WR-159A.

REFERENCES CITED

Cooper, H. H., and Jacob, C. E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history. Transactions American Geophysical Union, Vol. 27, pp. 526-534.

Jacob, C. E., 1940. On the flow of water in an elastic artesian aquifer. American Geophysical Union Transactions, Volume 21, Part II, pp. 574-585.

Jacob, C. E., 1950. Flow of groundwater, Chapter 5 in Engineering hydraulics, ed. H. Rouse, John Wiley & Sons, pp. 321-386.

Errol L. Montgomery & Associates, Inc., 1990. Results of hydrogeologic investigations, Brawley Wash pilot surface recharge site, Pima County, Arizona. Interim report prepared in association with CH2M Hill and Mr. L. G. Wilson for Tucson Water Planning Division, Hydrology Section, June 28, 1990.

TABLE 1. SUMMARY OF AQUIFER PARAMETERS FROM 20-DAY PUMPING TEST
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA

WELL NUMBER	SEMI-LOG GRAPHICAL PROCEDURE	LOG-LOG .....GRAPHICAL PROCEDURE.....		
	TRANSMISSIVITY[a]	TRANSMISSIVITY	STORAGE COEFFICIENT[b]	AVERAGE HYDRAULIC CONDUCTIVITY[c]
PUMPED WELL				
(D-16-10)8bdd[AF-64]	58,000 78,000 44,000	---	---	320
MONITOR WELL				
(D-16-10)8bdb1[WR-157A]	---	82,000	0.18	---
(D-16-10)8bcd[WR-158A]	---	97,000	0.11	---
(D-16-10)8bdb2[WR-159A]	---	79,000	0.20	---
(D-16-10)8bca1[WR-160A]	---	78,000	0.22	---

[a] Gallons per day per foot width of aquifer at 1:1 hydraulic gradient

[b] Dimensionless; ratio of volume water released per unit surface area of aquifer per unit decline in head

[c] Gallons per day per square foot of aquifer at 1:1 hydraulic gradient

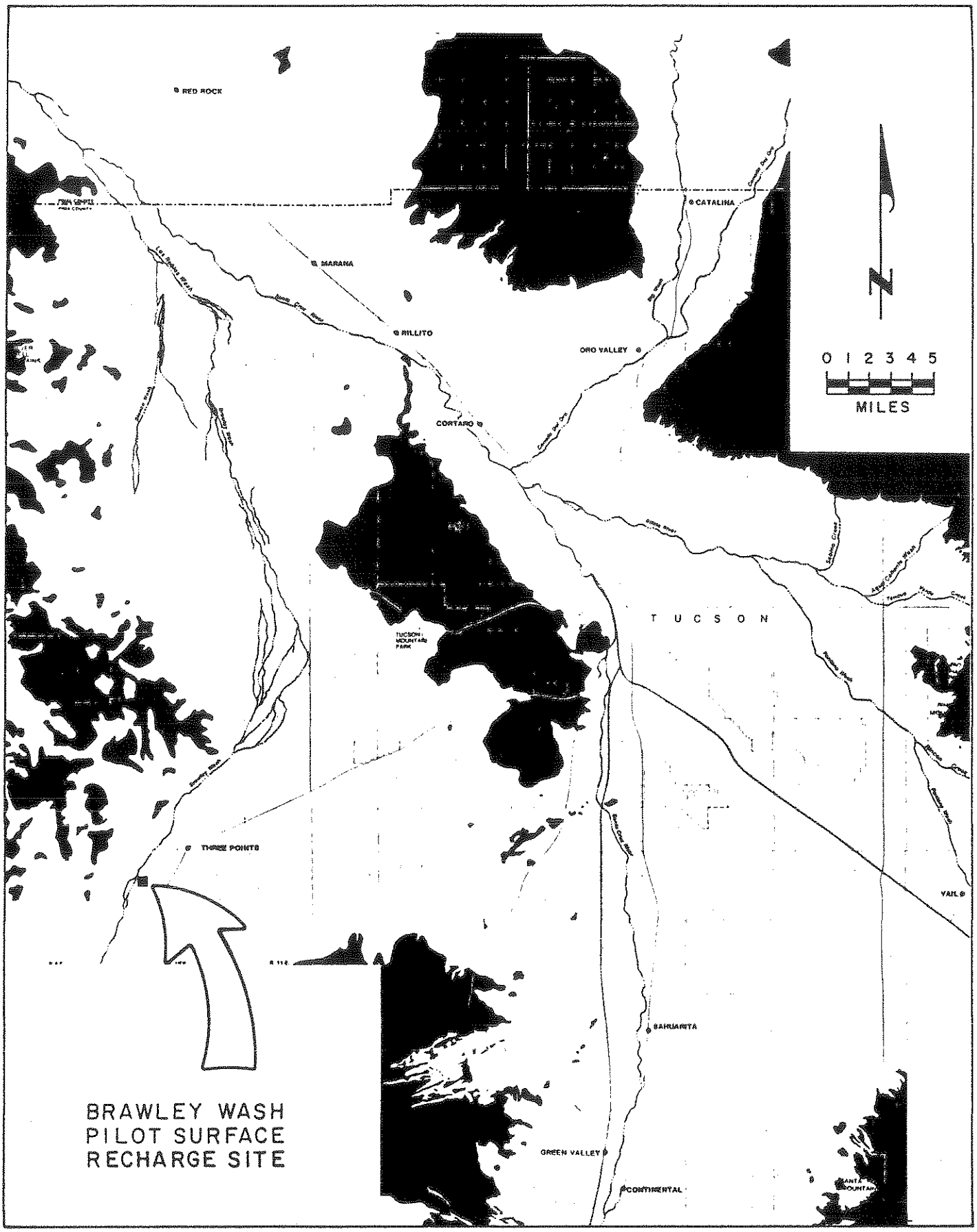


FIGURE 1. LOCATION OF BRAWLEY WASH PILOT SURFACE RECHARGE SITE

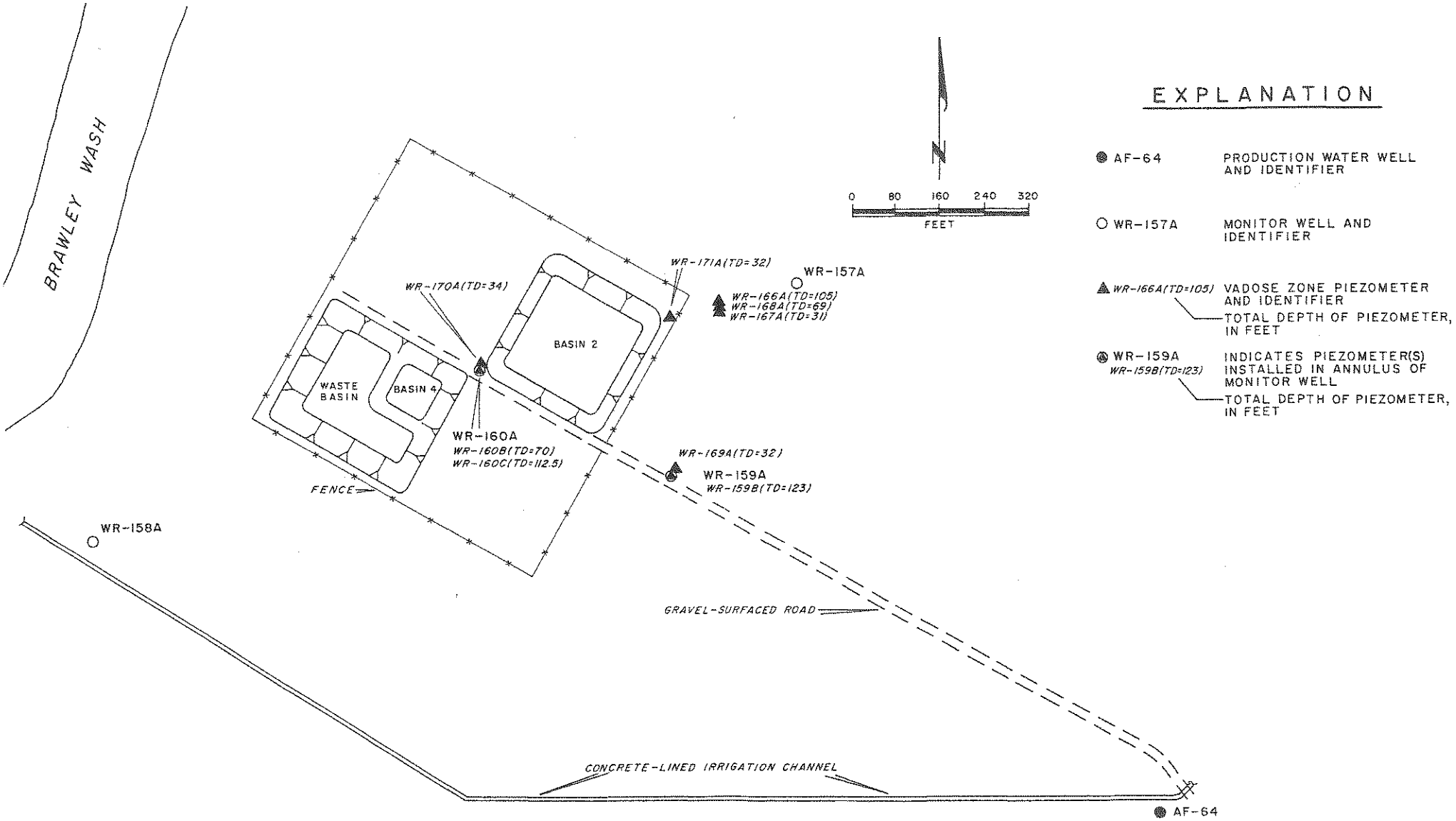


FIGURE 2. LOCATIONS OF WELLS AND PIEZOMETERS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

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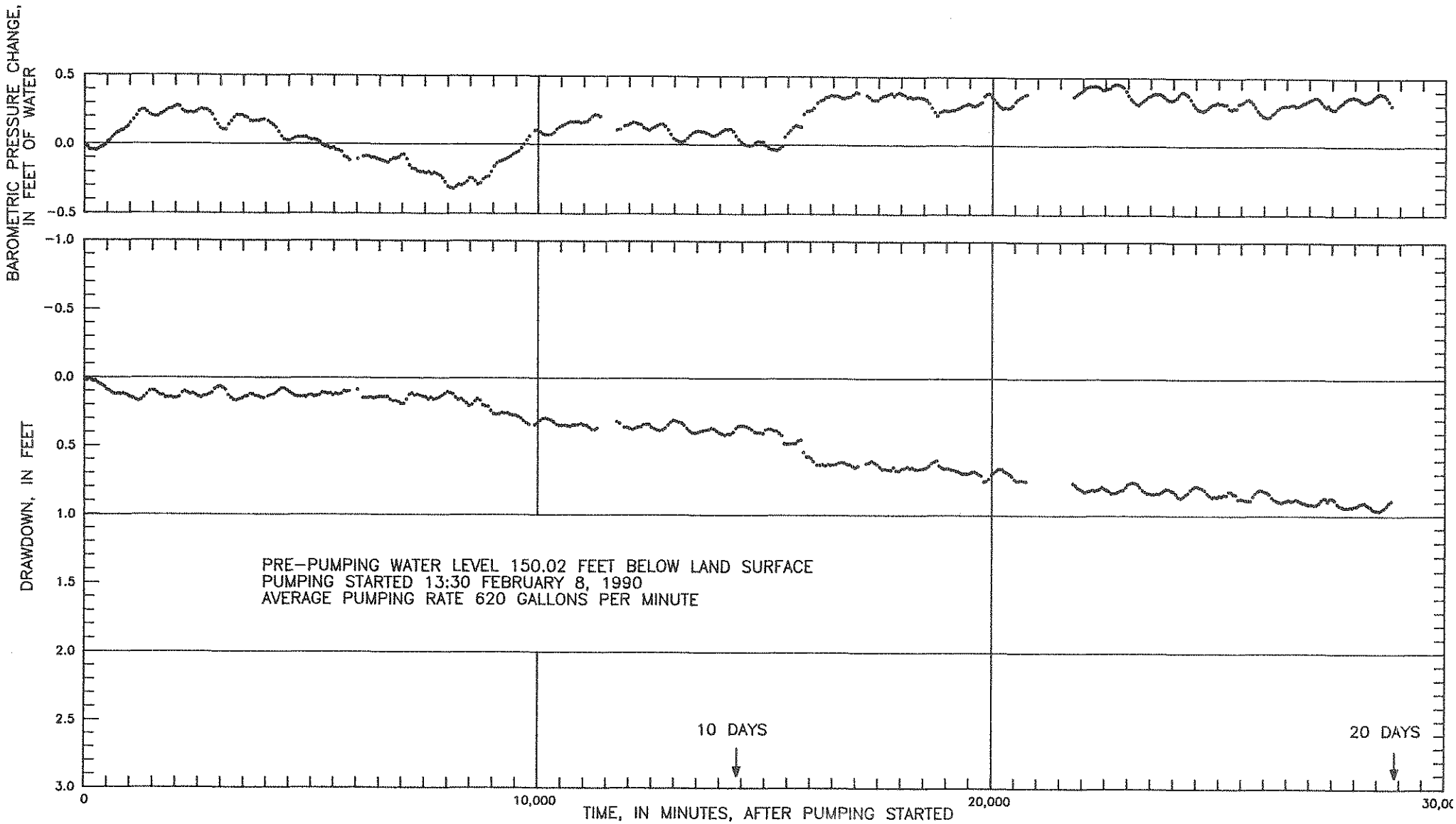

FIGURE 3. HYDROGRAPH FOR MONITOR WELL (D-16-10)8bdb1[WR-157A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

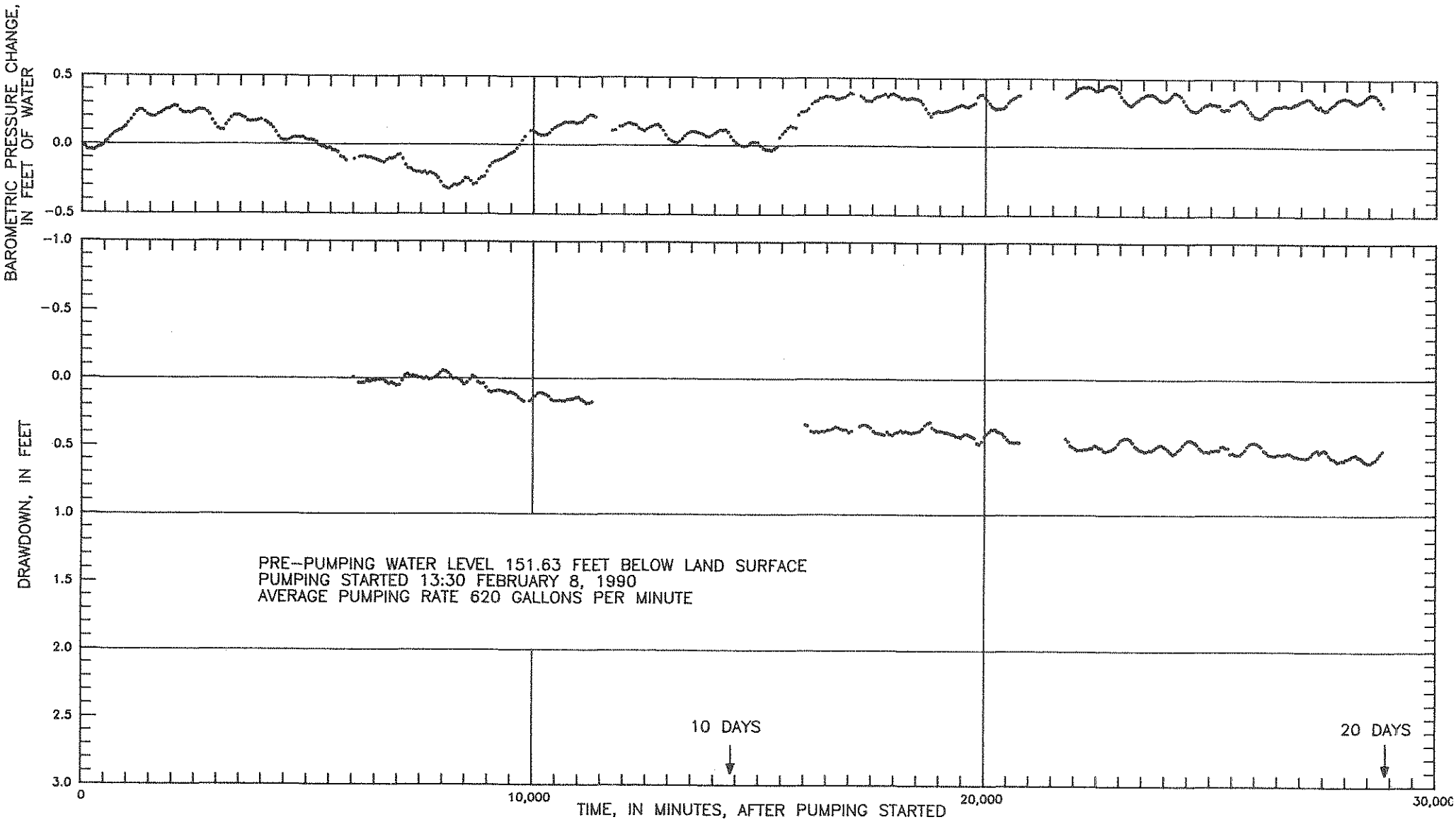

FIGURE 4. HYDROGRAPH FOR MONITOR WELL (D-16-10)8bcd[WR-158A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

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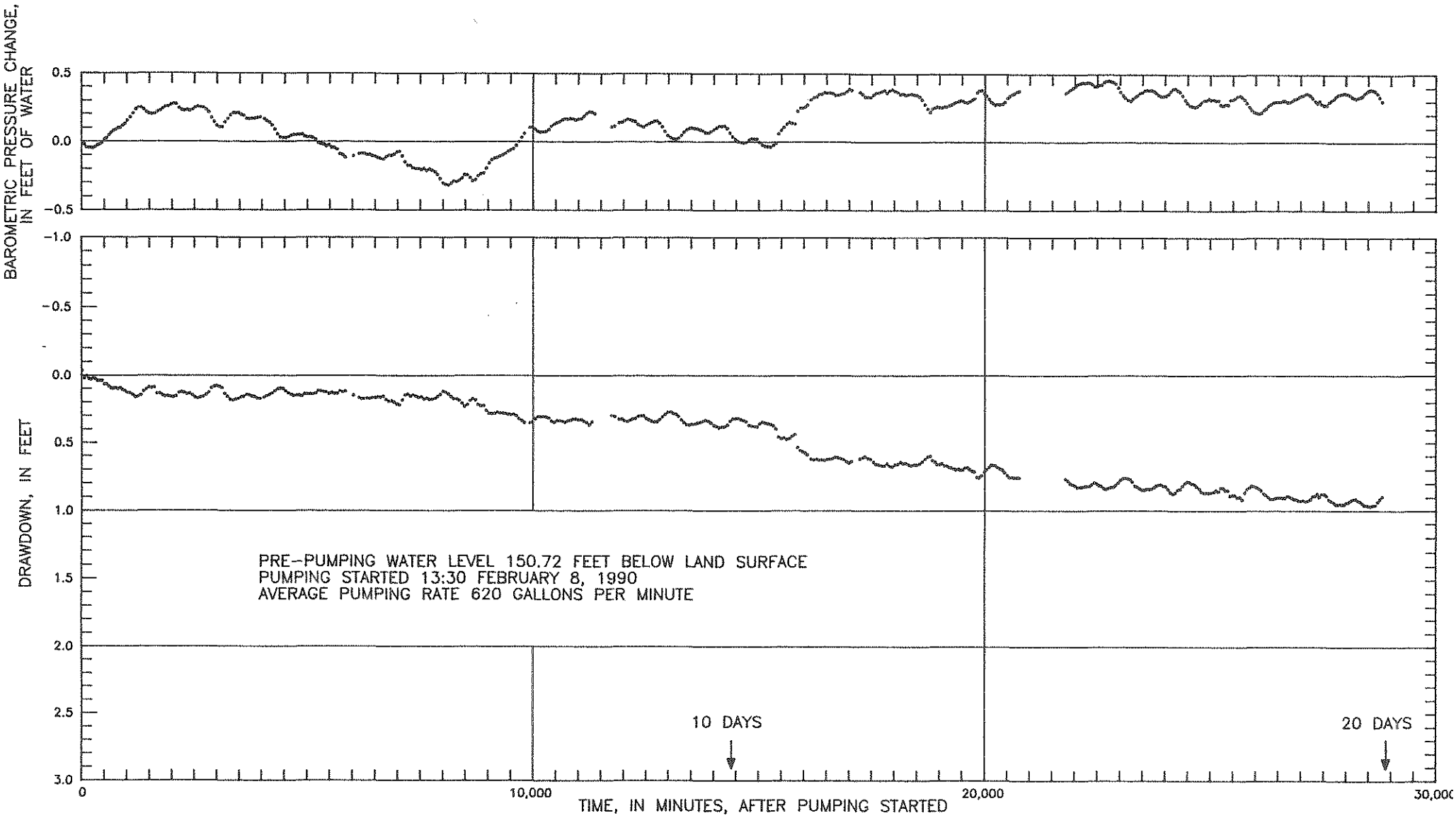

FIGURE 5. HYDROGRAPH FOR MONITOR WELL (D-16-10)8bdb2[WR-159A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

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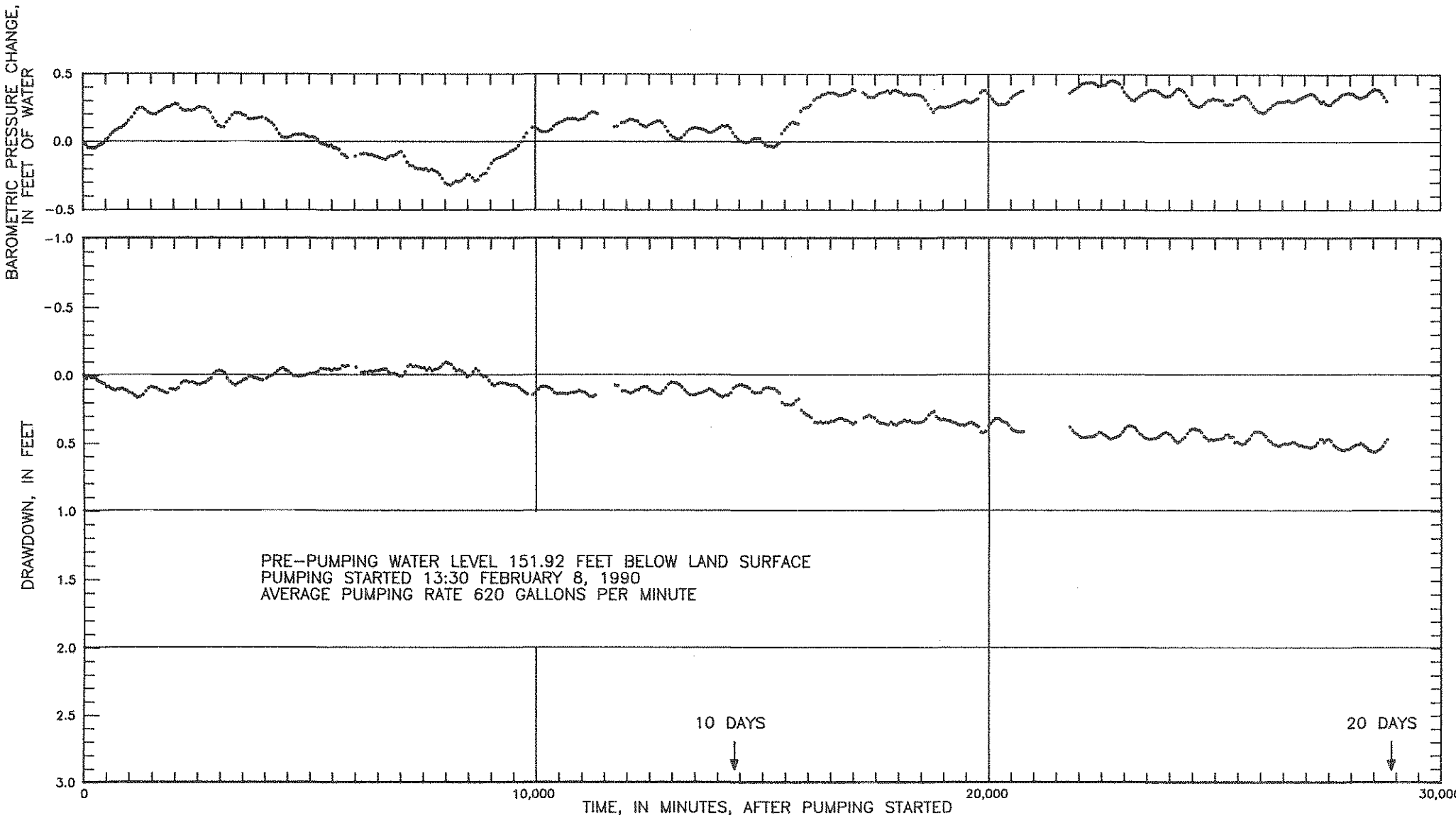

FIGURE 6. HYDROGRAPH FOR MONITOR WELL (D-16-10)8bca1[WR-160A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

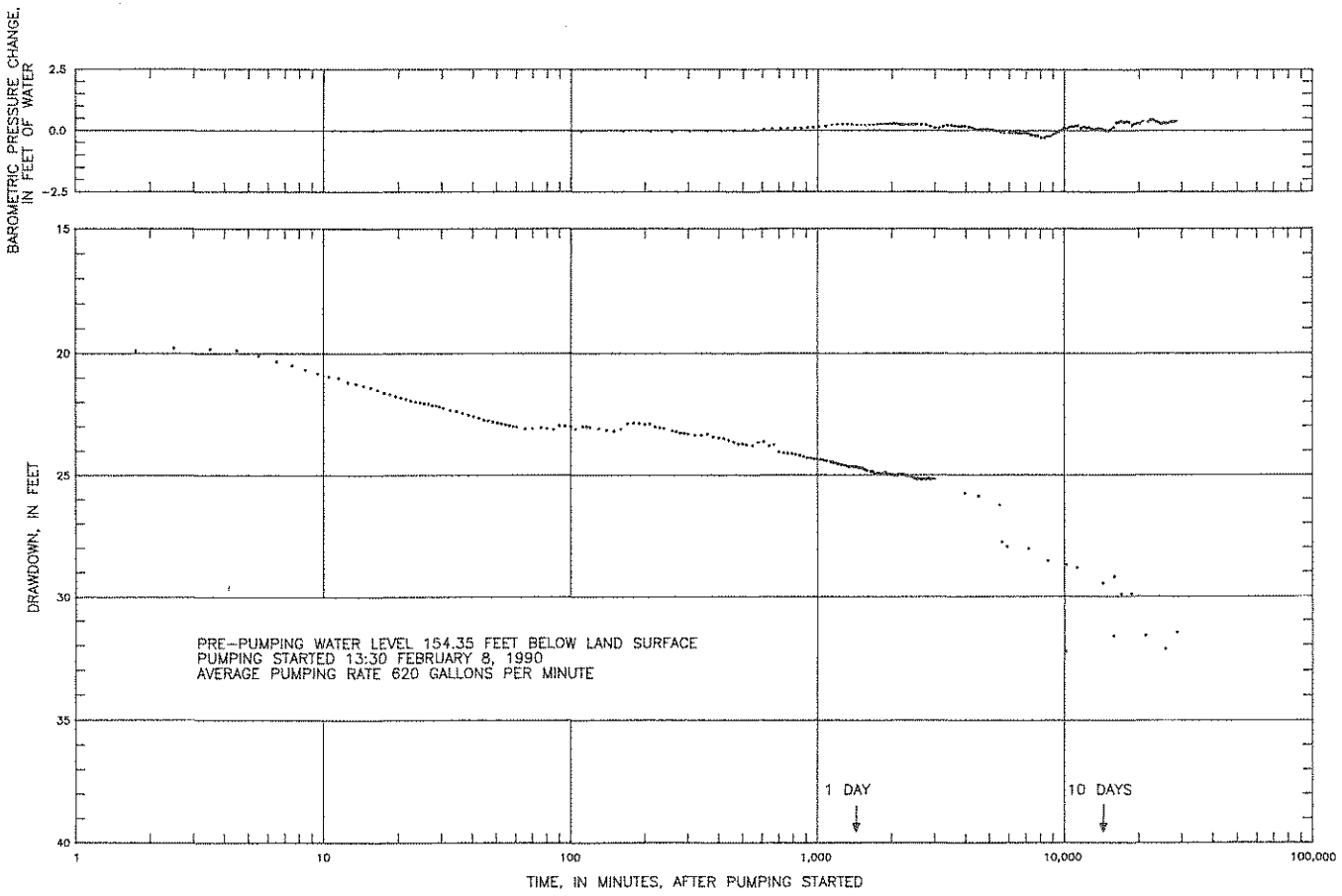

FIGURE 7. DRAWDOWN GRAPH FOR PUMPED WELL (D-16-10)8bdd[AF-64] DURING 20-DAY PUMPING TEST, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

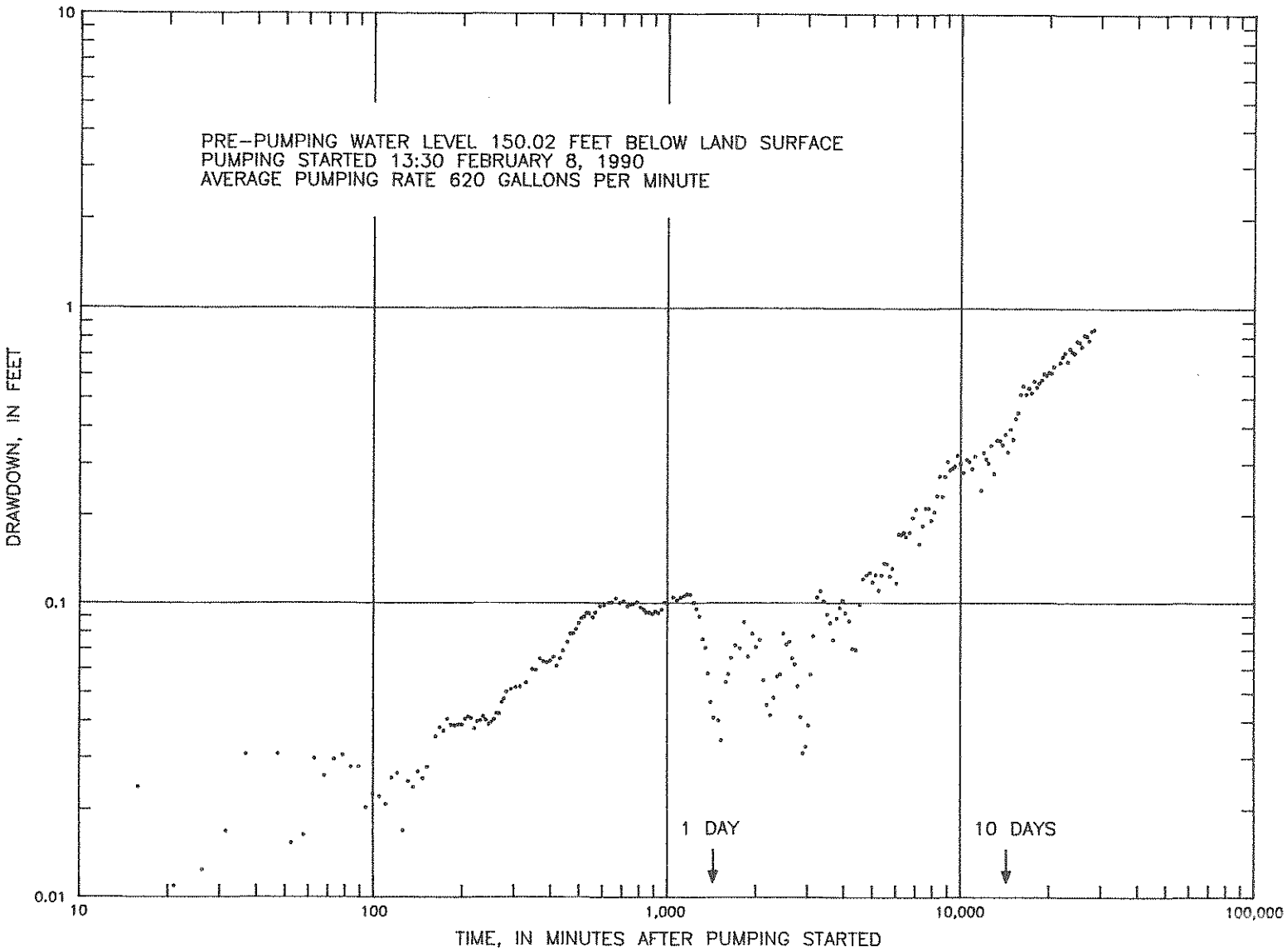

FIGURE 8. LOG-LOG DRAWDOWN GRAPH FOR MONITOR WELL (D-16-10)8bdb1[WR-157A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

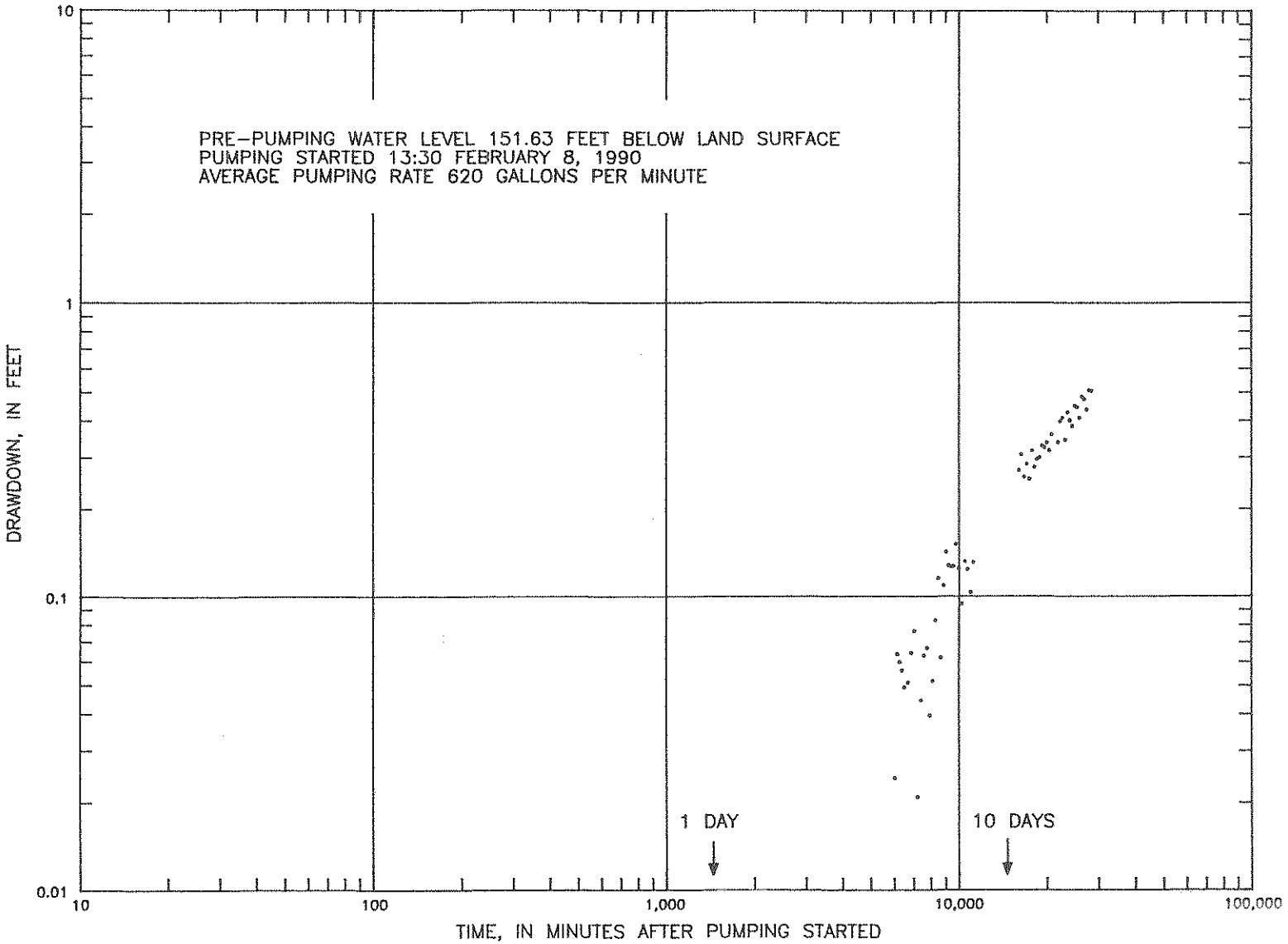

FIGURE 9. LOG-LOG DRAWDOWN GRAPH FOR MONITOR WELL (D-16-10)8bcd[WR-158A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

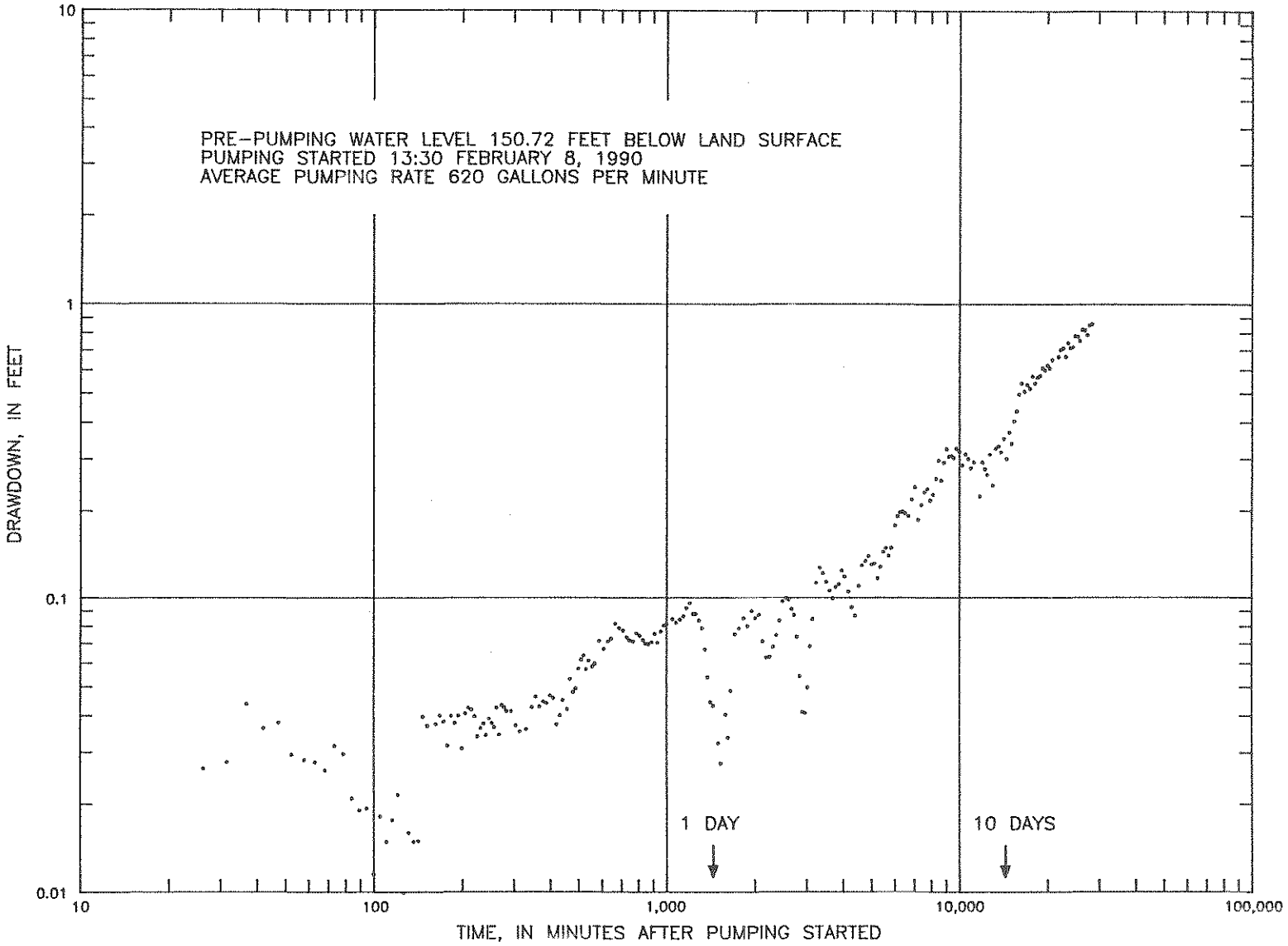

FIGURE 10. LOG-LOG DRAWDOWN GRAPH FOR MONITOR WELL (D-16-10)8bdb2[WR-159A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE

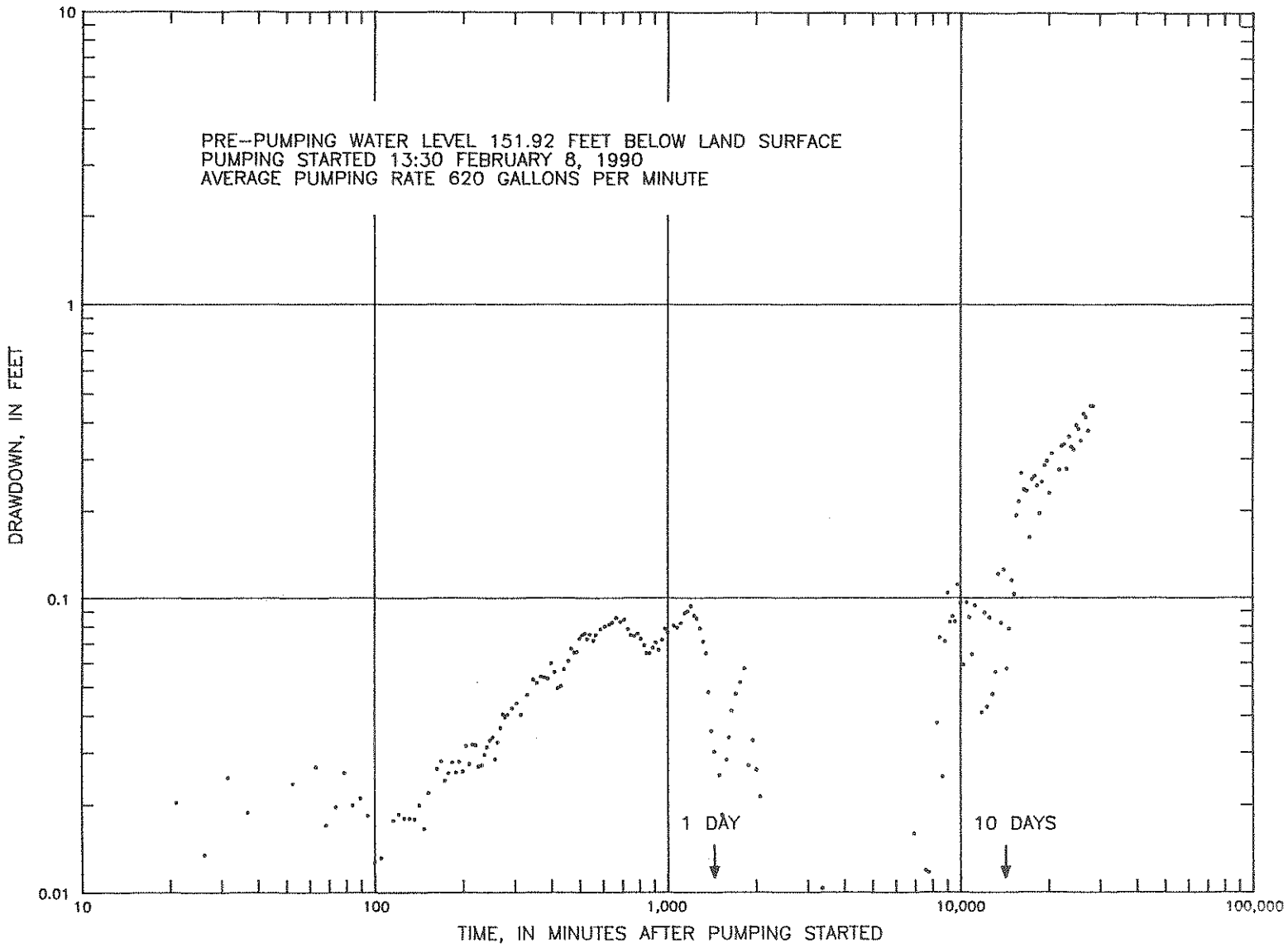

FIGURE 11. LOG-LOG DRAWDOWN GRAPH FOR MONITOR WELL (D-16-10)8bca1[WR-160A] DURING 20-DAY PUMPING TEST AT TUCSON WATER WELL AF-64 BRAWLEY WASH PILOT SURFACE RECHARGE SITE